Analysis of Pile Foundation of an Underground Building under the Influence of Tunnel Using PLAXIS 3D

A Thesis Submitted in Partial Fulfilment of the Requirements for the Degree of

Master of Technology

In

Civil Engineering

(Geotechnical Engineering)

By

Ram Manoharrao Deshpande

(213CE1042)

DEPARTMENT OF CIVIL ENGINEERING

NATIONAL INSTITUTE OF TECHNOLOGY, ROURKELA

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Under the Supervision of

Prof. N. Roy

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CERTIFICATE

This is to certify that the project entitled "**Analysis of Pile Foundation of an Underground Building under the Influence of Tunnel Using PLAXIS 3D**" submitted by **Mr. Ram Manoharrao Deshpande (Roll No. 213CE1042**) in partial fulfilment of the requirements for the award of Master of Technology Degree in Civil Engineering at NIT Rourkela is an authentic work carried out by him under my supervision and guidance.

To the best of my knowledge, the matter embodied in this report has not been submitted to any other university/institute for the award of any degree or diploma.

Place: Rourkela

Date:

Prof. N. Roy

Department of Civil Engineering

National Institute of Technology Rourkela

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Ram Manohararao Deshpande

ABSTRACT

Day by day competition is increasing for surface space, to fulfil the objective of sustainable development, use of subsurface space becomes very important. Underground structures being difficult and uneconomical to construct were restricted to only special structures like tunnels, hydropower stations, railway platforms, defence purpose buildings and mining. But presently, in a increasing number of cases, public buildings are also being built underground in some of the metro cities for many reasons, most common reason being effective use of land and location.

Construction of underground multi-storey building is provided with pile foundation. But in future, this pile foundation, being at large depths, may get affected by newly built tunnel passing close to it. This project mainly deals with analysis of pile foundation of building under the influence of tunnel with the use of finite element analysis software PLAXIS 3D.

For analysis purpose, a fully developed model was made and simulated for various positions and diameters of tunnel with respect to foundation of building. Results were analysed to find changes in the behaviour pile foundation in terms of total displacement. After thorough analysis of results of simulation, it was found that pile foundation of building is influenced by tunnel only when tunnel is in very close vicinity of pile and its influence is negligible if located far away from the structure. The distribution of internal forces induced by tunnel depend on the position of the pile with respect to the tunnel horizontal axis. The critical position of tunnel corresponds to pile with a tip just below of the tunnel. When tunnel is located at various depths, the variation of total displacement with depth of pile depends upon position of tunnel and the tip of pile. The diameter of tunnel also has small influence on displacement of pile. Displacement of pile is also influenced by diameter of tunnel to a small extent.

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Cu	**Undrained shear strength**
c	**Cohesion**
Φ	**Friction angle**
d	**Thickness**
E	**Young's Modulus**
E_{oed}	**Odeometer Modulus**
OCR	**Over-consolidation ratio**
Q	**Shear Force**
u	**Displacement**
n	**Porosity**
G	**Shear modulus**
β	**Inclination angles**
x^{ref}	**denotes reference value**
K_0	**Coefficient of lateral Earth Pressure (Initial Stress State)**
R_f	**Failure ratio**
$\gamma_{un\text{-}sat}$	**Unsaturated soil weight**
γ_{sat}	**Saturated soil weight ν Poisson ratio**
ψ	**Dilatancy angle**
e_{init}	**Initial void ratio**
e_{max}	**Maximum void ratio**
e_{min}	**Minimum void ratio**
ν	**Poission's ratio**

CHAPTER 1
INTRODUCTION

1.1. Need of Underground Construction

For hundreds of years, our natural dominion has been the surface of the ground. Insisted by necessity and curiosity, we have always tried to escape from this space, by searching for utilization of the remaining dimension, upwards or downwards. In these struggles, we have always encountered great difficulties, especially in the downward direction. Only the underground space can provide us the site for activities or infrastructures that are needed in the populated metro cities. Underground construction works have always been very difficult. However, rapid economic development in recent century made us dig in to the soil deeper and deeper, encouraged by numerous reasons.

Today, the main reasons which justify use of the underground space can listed as follows-

i. Land use & location

Presently, every mega city is fighting a losing battle for open spaces over the last few years. In fact this lack of space above the surface is not only the case in metro cities but in almost all cities around the world. It leaves us no option but to make use of the underground space in a more thoughtful and a well-organized way so that the advantage of location can be utilised.

ii. Isolation considerations

The soil is almost infinitely spaced, fully opaque and gives us many advantages in terms of isolation. It can provide protection against extreme climate, earthquakes and other natural disasters.

iii. Environmental preservation

Recent research suggests that a variety of the underground building cases the annual energy demand is below 10 kWh/m2, so we can almost consider such buildings as zero-energy buildings. . This is notably important aspect in designing facilities with a low environment impact. The ground can also provide us a variety of rewards in terms of safeguard of the surroundings, such as Aesthetics or ecology

iv. Topographic reasons

Tunnels have been made in undulated surfaces, mainly to dig through mountains for both roads and railways. The use of tunnel advances or makes it possible several transport options, like roads, railways, canals, etc. in hilly and mountainous areas.

v. Economic reasons

Because the initial construction cost of underground buildings is generally higher than those of building in the open air, underground buildings are in a way “punished” when linked to open air buildings. Therefore, the economic paybacks of an underground structure should be evaluated by estimating the life-cost impacts of the reimbursements provided by such structures. Additionally, the evaluation should take into consideration the various indirect rewards they offer, especially in terms of low environmental impact. If executed systematically Initial building costs can be made low, as underground building is largely subtractive rather than additive, and because the soil displaced by the excavation can be used again as building materials.

1.2 Tunnelling in Urban Area

As tunnelling expenses continue to drop, tunnelling is being considered as the best option to avoid increasing traffic congestion in urban areas. Tunnels can be used to take heavy traffic from one point of city to other so that local roads can be freed up, improving the dependability of bus service, making cycling possible. In practical, tunnels can rebuild the city, generate returns in long term by letting networks of roads to be born-again and collectively improving the liveability of whole urban areas.

There are many reasons for which tunnels are being preferred more these days, some of them are mentioned below.

The cost of tunnel construction is falling by about four per cent each year, compared to surface roads in urban area where acquiring land or moving utilities is expensive construction urban tunnels can be considered as a cheaper option.

Technology for tunnel boring and constructing underground structures have made rapid advance as a result of the channel tunnel and other projects which involved new technologies in place of blasting. These new techniques have transformed the economics of tunnelling where the right geology exists. New cross-sections have been developed which carry two levels of light vehicles in a single tube slashing the cost of tunnel provision

Harmful pollutants in tunnels can now be collected before ventilation and “scrubbed” near clean using new technologies, whereas vehicle emissions on surface streets flow straight into the air.

1.3 The Tunnel-Structure Interaction Problem and Objective of the Project

Considering the ‘no-option’ scenario, there is intense need of construction of tunnel under very high dense urban areas. The construction and operation of these systems can damage to surface structures or other underground structures. Therefore the prediction of tunnel induced stresses becomes an important issue in the planning and execution process. The current design approaches which we have are very conventional and may cause excessive spending in the design and construction. A better understanding of tunnelling induced deformations could decrease expenditures and help us escape disputes and resolve claims.

The issue of interaction between tunnel and adjacent structures is of major research for tunnelling in metro cities, because of the high interaction between tunnelling and existing structural components of building. A foremost problem during the planning and execution of underground construction is the influence of construction related ground movements on adjacent structural components of building. During excavation and support of tunnels and open-cuts, changes in the state of stress in the ground mass around the excavation and loss of ground occur. These deviations in stress and ground losses are normally expressed in the form of vertical and horizontal ground movements. The ground movements, in turn, will cause any structures supported by the affected ground to translate, rotate, deform, distort, and possibly sustain damage. As a result, important tasks facing both the engineer and the contractor are the estimation of the magnitude and distribution of the ground movements to be caused by the construction procedures and the tolerance of the structures and utilities to the deformations and distortions sustained as a result of the ground displacements.

This project presents a thorough FEM analysis performed using PLAXIS 3D software, related to the influence of tunnelling in soft soils on pile foundation of adjacent building. For this, soil model and structural model of building having pile foundation and with five underground floors was made and simulated the same model for different position of tunnel with respect to the building. Main objective of the project is to perform FEM analysis using FEM software PLAXIS 3D and to find out effect of tunnelling on the pile foundation of adjacent building in terms of total displacement. In order to effectively analyse the effect of tunnel on adjacent pile, the distance between tunnel and pile foundation is varied. Also two different diameter tunnels are used in order effect of diameter of tunnel on pile foundation.

CHAPTER 2

LITERATURE REVIEW

Though FEM analysis software like PLAXIS 2D/3D, GEO5, FLAC 2D are relatively new software in the field of geotechnical engineering, yet many researches were done great work recently on underground structures, deep excavation, tunnelling and tunnel-structure interaction. Some of them are mentioned here with their findings.

Mroueh H. and Shahrour I. (2002) did analysis of the impact of construction of urban tunnels on adjacent pile foundations. It was carried out using an elastoplastic three-dimensional finite element modelling. Numerical simulations were performed in two stages, which concern, respectively, the application of the pile axial loading and the construction of the tunnel in presence of the pile foundations. Analysis was carried out for both single piles and groups of piles. Results of numerical simulations show that tunnelling induces significant internal forces in adjacent piles. Analysis of the interaction between tunnelling and a group of piles reveals a positive group effect with a high reduction of the internal forces in rear piles

Brinkgreve R.B.J. et al (2003), studied the advancement of a tunnel boring machine in the ground. It was concluded that soil stiffness plays an important role in predicting the width of the settlement trough and consequently the influence on adjacent buildings.

Huang X. and Schweiger H. F (2010) studied influence of deep excavations on existing tunnels in Shanghai using PLAXIS-GiD. The hardening soil constitutive model was used because it suits the soil found in Shanghai. Parameters studied were relative position of tunnel with respect to excavation, tunnel diameter, excavations dimensions and tunnel protection measures.

The results clearly indicate that for situations where the excavation is located directly above the tunnel, deformation of the tunnel will occur and additional forces are introduced into the lining. However, when the excavation is moved to the side of the tunnel, the influence on the tunnel is not significant. Though the distance between excavation and tunnel influenced the tunnel lining. In general, if ‘w’ is width of excavation then tunnels is not at all influenced beyond a distance of five times of ‘w’.

Schweckendiek Timo (2007) studied structural reliability analysis of deep excavations using PLAXIS generic probabilistic toolbox called “Pro Box”, which performs reliability analysis automatically with output of PLAXIS. The influence coefficients as result of the analysis provide useful information for optimization purposes and also for the physical understanding of the model behaviour close to failure.

Stoel Van Der et all.(2007) studied risk management during renovation of the new Rijksmuseum Amsterdam. The geotechnical design calculations are carried out by using the PLAXIS. The calculations are part of the risk assessment strategy in order to predict and judge the influence of ground deformations due to the excavations on the surrounding building. Horizontal deformation of the sheet pile wall, horizontal and vertical deformations in a horizontal cross-section at surface level were determined from analysis.

Rodriguez J.A.(March 2005) carried out study on deep excavation in soft soils and complex ground water conditions in Bagota, capital city of Columbia. Valuable information has been gathered about the behaviour of slurry walls and the soil anchor system used for the excavation of the project in soft soil conditions with diffi-cult water conditions in the piedmont of Bogotá eastern hills. From the analysis of this case it can be concluded that the computational model and the soil models used, considering the coupled problem of deformation and water flow, the highly non-linear behaviour of the soils and the construction sequence, allow detailed study of complex excavations in sectors with especially difficult geotechnical conditions in the short term.

Zhandos Y. Orazalin and Andrew J. Whittle (April 2014) carried out finite element analysis of a complex excavation. The project involved a complex sequence of berms, access ramps and phased construction of the concrete mat foundation. The non-uniform soil excavation resulted in the three-dimensional effects which were well-captured by the 3D model predictions. The analysis results show a good agreement with the measured data and provide keys to explain many features of the observed performance including the differences in diaphragm wall deformations associated with sections supported by tieback anchors. A general pattern of measured movements at the centre of a wall typically correspond to an initial cantilever movement of approximately 10-20 mm during the excavation to the first tieback support level.

Pornkasem Jongpradist et all.(October 2012) performed numerical simulations of geotechnical works in Bangkok subsoil using advanced soil models available in PLAXIS. Three constitutive models with enhancing levels of complexity are used to simulate three types of geotechnical works (embankment construction, deep excavation and tunnelling) on Bangkok subsoil conditions. All problems which are from well-documented case histories having reliable monitored data are analysed by PLAXIS 2D assuming plane strain condition with the appropriate analysis condition

CHAPTER 3

METHODOLOGY

3.1 Introduction: Finite Element Method

The finite element method (FEM) is a numerical method for finding fairly accurate solutions of partial differential equations as well as integral equations. The solution approach is based either on eliminating the differential equation completely (steady state problems), or rendering the PDE into an approximating system of ordinary differential equations, which are then numerically integrated using standard techniques such as Euler's method

For carrying out elasto-plastic analysis in this project, commercially available geotechnical software PLAXIS 3D is being used which uses Finite Element Analysis (FEA) for simulation of model.

PLAXIS 3D

PLAXIS 3D is a finite element analysis software generally used for three-dimensional analysis of deformation and stability in geotechnical engineering. It is embedded with features to find solution to various aspects of complex geotechnical structures and construction processes using robust and theoretically sound computational procedures. Complex geometry of soil and structures can be defined in two different modes, which is one of the advantages of PlAXIS 3D. These modes are specifically defined for soil or structural modelling. In this software, independent solid models can automatically be intersected and meshed. The staged constructions mode is another advantage, this mode enables a realistic simulation of construction and excavation processes by activating and deactivating soil volume clusters and structural objects, application of loads, changing of water tables, etc.

The output consists of a full suite of visualization tools to check details of the complex inner structure of a full 3D underground soil-structure model. PLAXIS 3D is a very much user friendly 3d geotechnical program, which offers flexible and interoperable geometry, realistic simulation of construction stages, a robust and reliable calculation kernel, and comprehensive and detailed post-processing, making it a complete solution for daily geotechnical design and analysis.

3.2 Soil Layer and Structural Elements

Current model of this problem consists of a tunnel and building having five underground floors and ten floors above surface having load of 5 KN per square metre. This model is modelled with use of soil layers as well as structural elements like plate, pile, anchor and beam elements in PLAXIS 3D. Details of these elements are as follows-

1. **Soil Layers**

   The soil stratigraphy can be defined in the soil mode using the borehole feature of the program. Boreholes are locations in draw area at which the information on the position of soil layers and the water table is given. If multiple boreholes are defined the program will automatically interpolate between boreholes, and derive the position of the soil layer from the borehole information.

   Groundwater and pore pressures play an important role in the soil behaviour, so this requires proper definition of water conditions. This definition of water conditions can also be done with the creation of borehole.

2. **Fixed-end Anchor Element**

   A fixed-end anchor is a point element that is attached to a structure at one side and fixed to the world at the other side. Fixed-end anchors can be used to simulate piles in a simplified way, i.e. without taking into account pile-soil interaction. Alternatively, fixed end anchors can be used to simulate anchors or props to support retaining walls.

3. **Beams**

Beams are structural objects to model slender (one-dimensional) structures with a significant flexural rigidity (bending stiffness) and axial stiffness. The creation of a beam is similar to the creation of geometry line.

4. **Embedded Piles**

An embedded pile is a pile composed of beam elements that can be placed in arbitrary direction in the sub-soil and that interacts with the sub-soil by means of special interface elements. The interaction may involve a skin resistance as well as a foot resistance. The skin friction and the tip force are determined by the relative.

5. **Plates**

Plates are structural objects used to model thin two-dimensional structures in the ground with a significant flexural rigidity. The creation of a plate is similar to the creation of a geometry surface.

6. Interfaces

Interfaces are joint elements to be added to plates or geogrids to allow for a proper modelling of soil-structure interaction. Interfaces may be used to simulate, for example the thin zone of intensely shearing material at the contact between a plate and the surrounding soil. Interfaces can be created next to plate or geogrid element or between two soil volumes.

3.3 Procedure used for Simulation and Analysis of Project

Following flowchart explains procedure adopted for the simulation of each model having unique position of tunnel with respect to pile foundation of building.

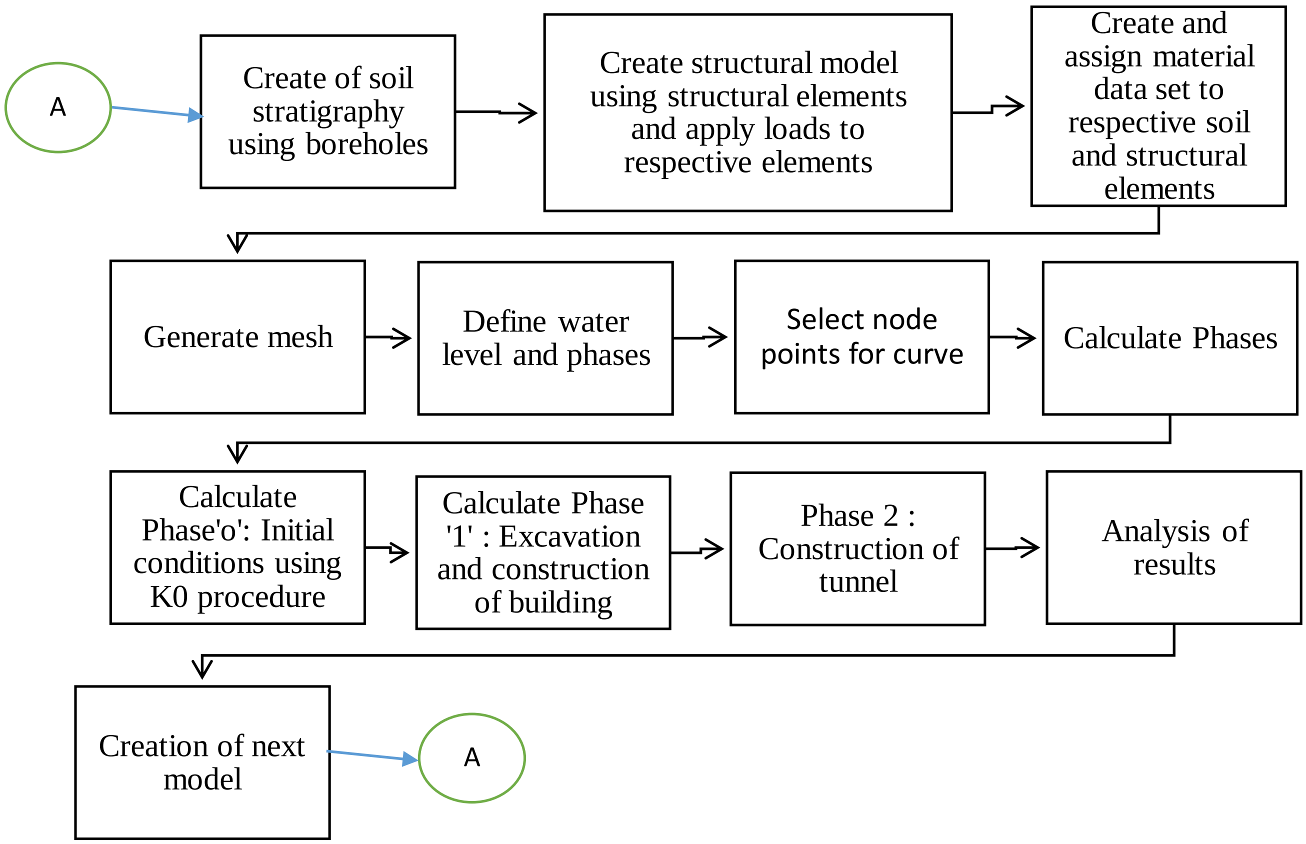


Figure 1 Flow chart showing procedure used for Simulation and Analysis of Project

3.4 Details of Current Model

The soil model created for model closely resembles with soil stratigraphy found in Mumbai region. Mumbai city soil is mostly made of sandy clay, loam and the fractured basalt rock. The clay properties vary along with depth up to 30 m deep, then starts fractured basalt rock extending to a large depth as shown in figure 2.

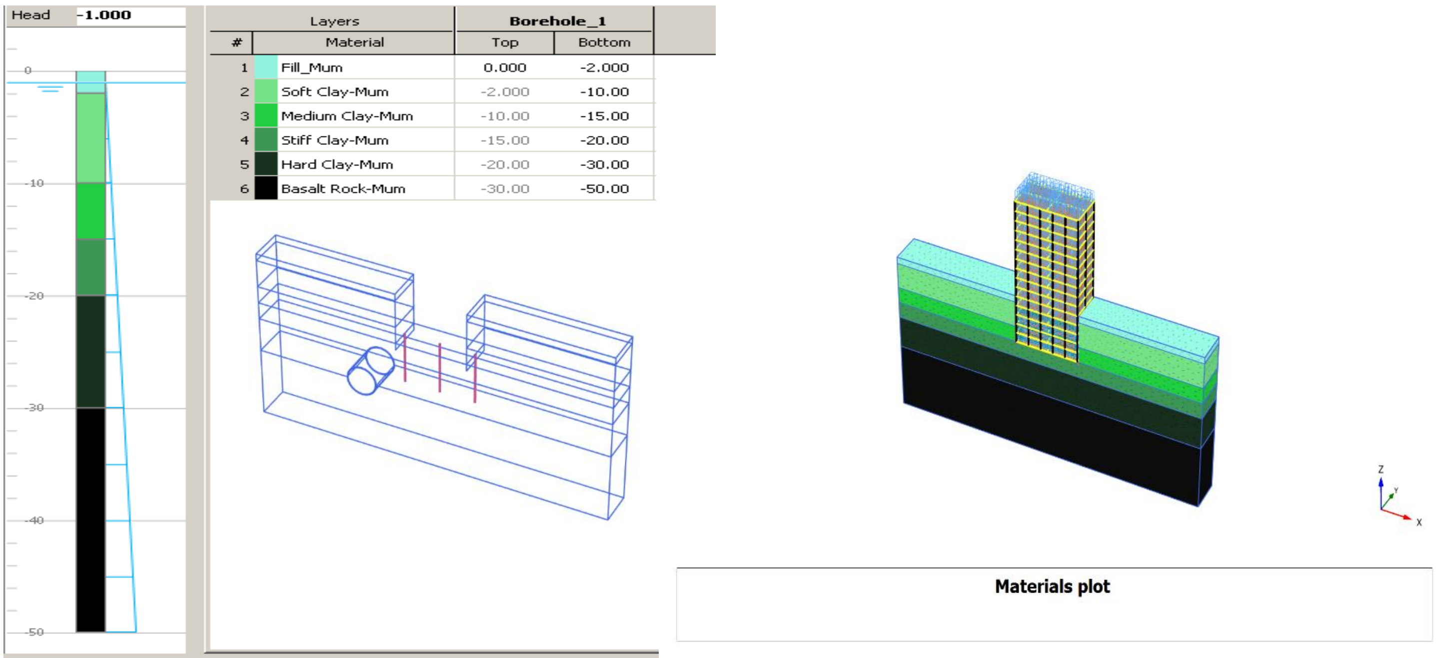


Figure 2 Soil Stratigraphy used for model

Table 1 Materials - Soil and interfaces

Identification	Unit	Stiff Clay-Mum	Medium Clay-Mum	Hard Clay-Mum	Basalt Rock-Mum
γ_{unsat}	kN/m^3	16.00	16.00	16.00	17.00
γ_{sat}	kN/m^3	18.00	18.00	18.00	20.00
e_{init}		0.5000	0.5000	0.5000	0.5000
e_{min}		0.000	0.000	0.000	0.000
e_{max}		999.0	999.0	999.0	999.0
E	kN/m^2	15.00E3	7.000	30.00E3	30.00E6
ν (nu)		0.3500	0.3500	0.3500	0.3000

Identification		Fill_Mum	Soft Clay-Mum
γ_{unsat}	kN/m^3	16.00	16.00
γ_{sat}	kN/m^3	20.00	17.00
e_{init}		0.5000	0.5000
e_{min}		0.000	0.000
e_{max}		999.0	999.0
E_{50}^{ref}	kN/m^2	22.00E3	2000
E_{oed}^{ref}	kN/m^2	22.00E3	2000
E_{ur}^{ref}	kN/m^2	66.00E3	10.00E3
C_c		0.01568	0.1725
C_s		4.705E-3	0.03105
e_{init}		0.5000	0.5000
c_{ref}	kN/m^2	1.000	5.000
φ (phi)	°	30.00	25.00
ψ (psi)	°	0.000	0.000
K_0^{nc}		0.5000	0.5774
R_f		0.9000	0.9000

Relevant properties of other structural materials are given in the table 2 onwards.

Table 2 Materials – Anchors

Identification		Anchors- Column
Material type		Elastic
EA	kN	2.500E6

Table 3 Materials - Plates

Identification		Basement	Rest of building excluding vertical walls	Vertical wall
D	M	0.3000	0.3000	0.3790
Γ	kN/m^3	50.00	33.33	2.550
Isotropic		Yes	Yes	No
E_1	kN/m^2	30.00E6	30.00E6	14.60E6

E_2	kN/m^2	30.00E6	30.00E6	730.0E3
G_{12}	kN/m^2	15.00E6	15.00E6	730.0E3
G_{13}	kN/m^2	15.00E6	15.00E6	1.270E6
G_{23}	kN/m^2	15.00E6	15.00E6	382.0E3
Rayleigh α		0.2320	0.2320	0.000
Rayleigh β		8.000E-3	8.000E-3	0.000

Table 5 Materials - Embedded piles

Identification		**Pile foundation**
E	kN/m^2	30.00E6
Γ	kN/m^3	6.000
Pile type		Predefined
Predefined pile type		Massive circular pile
Diameter	m	1.500
A	m^2	1.767
I_3	m^4	0.2485
I_2	m^4	0.2485
Skin resistance		Linear

Table 4 Materials – Beams

Identification		**Strut**	**Waling**	**Beam**
A	m^2	7.367E-3	8.682E-3	0.7000
γ	kN/m^3	78.50	78.50	6.000
E	kN/m^2	210.0E6	210.0E6	30.00E6
I_3	m^4	0.05073E-3	0.1045E-3	0.05800
I_2	m^4	0.05073E-3	0.3660E-3	0.02900

3.5 Model Designations

Models are broadly divided into two categories depending upon diameter of tunnel. Tunnel ‘A’ having diameter of D=4.25 m and Tunnel ‘B’ having diameter of D=15 m, as shown in Figure 3 & 4

Furthermore, depending upon position of tunnel with respect to building various models are made as shown in figure 5 and Table 6

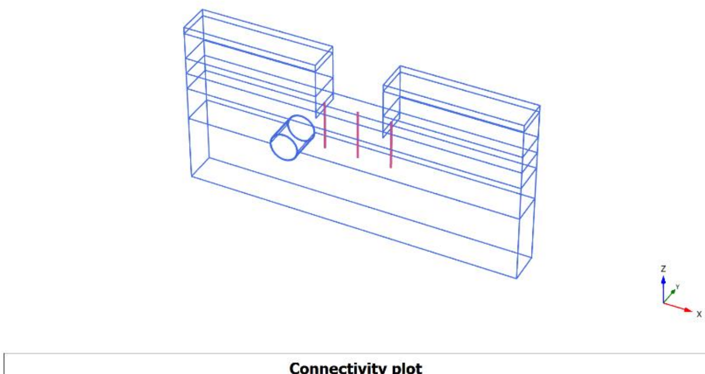


Figure 3 Tunnel A with outer diameter D=4.25 m

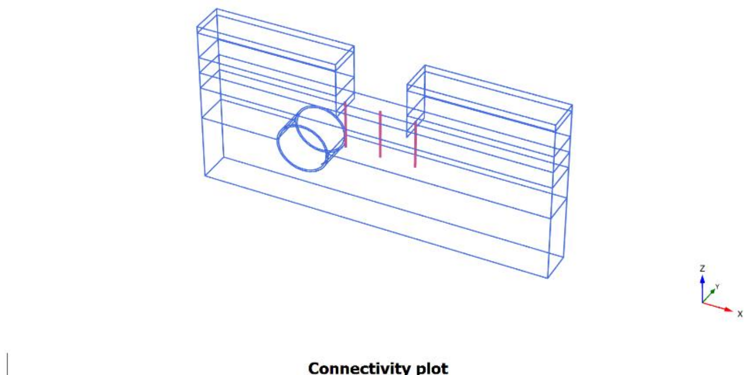


Figure 4 Tunnel B with outer diameter D=15 m

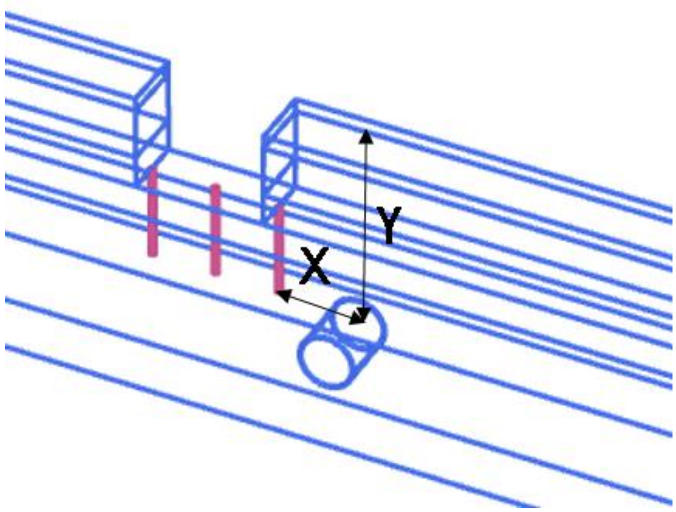


Figure 5 Position of Tunnel with respect to Building

X (In Meters) is Horizontal Distance Between Centre of Tunnel & Nearest Pile and **Y** (In Meters) is Vertical Distance Between Centre of Tunnel & Ground Surface

Table 6 Position of Tunnel with respect to Building

Model Name	Horizontal Distance Between Centre of Tunnel & Nearest Pile X (In Meters)	Vertical Distance Between Centre of Tunnel & Ground Surface Y (In Meters)
20-AT-5	5	-20
20-AT-6	6	-20
20-AT-7	7	-20
20-AT-8	8	-20
20-AT-9	9	-20
20-AT-10	10	-20
20-AT-15	15	-20
20-AT-20	20	-20
25-AT-5	5	-25
25-AT-6	6	-25
25-AT-7	7	-25
25-AT-8	8	-25
25-AT-9	9	-25
25-AT-10	10	-25

25-AT-15	15	-25
25-AT-20	20	-25
30-AT-5	5	-30
30-AT-6	6	-30
30-AT-7	7	-30
30-AT-8	8	-30
30-AT-9	9	-30
30-AT-10	10	-30
30-AT-15	15	-30
30-AT-20	20	-30
35-AT-5	5	-35
35-AT-6	6	-35
35-AT-7	7	-35
35-AT-8	8	-35
35-AT-9	9	-35
35-AT-10	10	-35
35-AT-15	15	-35
35-AT-20	20	-35
20-BT-10	10	-20

20-BT-15	15	-20
20-BT-20	20	-20
20-BT-25	25	-20
25-BT-10	10	-25
25-BT-15	15	-25
25-BT-20	20	-25
25-BT-25	25	-25
30-BT-10	10	-30
30-BT-15	15	-30
30-BT-20	20	-30
30-BT-25	25	-30
35-BT-10	10	-35
35-BT-15	15	-35
35-BT-20	20	-35
35-BT-25	25	-35

CHAPTER 4

RESULTS AND DISCUSSIONS

There were 16 models of Tunnel ‘B’ and 32 models of Tunnel ‘A’, which were simulated and analysed for result.

For better understanding let us analyse one model -30-AT-5- Which means tunnel having diameter of 4.25 m is located at 30m depth and at a horizontal distance of 5m from the pile

4.1 Variation of maximum total displacement of pile

Because of construction of tunnel the pile foundation is affected, maximum total displacements shown in figure 6 and 7 depict the evolution of the displacement of the structure foundations after tunnelling. Though the displacement is small (0.25 mm), it shows that the lateral displacement of each foundation increases after tunnel is built.

Figure 6 Maximum total displacement of pile without tunnel=12.62 mm

Figure 7 Maximum total displacement of pile with tunnel=12.37 mm

4.2 Variation of total displacement over depth of pile

The total displacement of the pile varies with depth as shown in figure 8. Displacement is maximum at the depth of 30 m, which suggests that displacement is more at the depth of centre of tunnel.

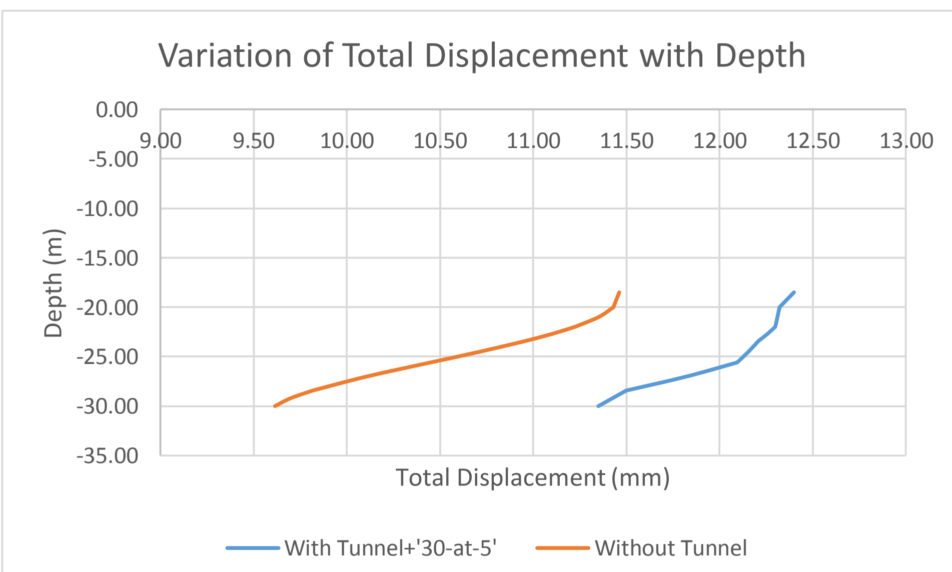


Figure 8 Total displacement of pile with and without tunnel-30-AT-5

4.3 Variation of total displacement of pile over depth of pile, because of tunnel 'A' at various horizontal distances from the pile:

The variation is shown in figure 9 below

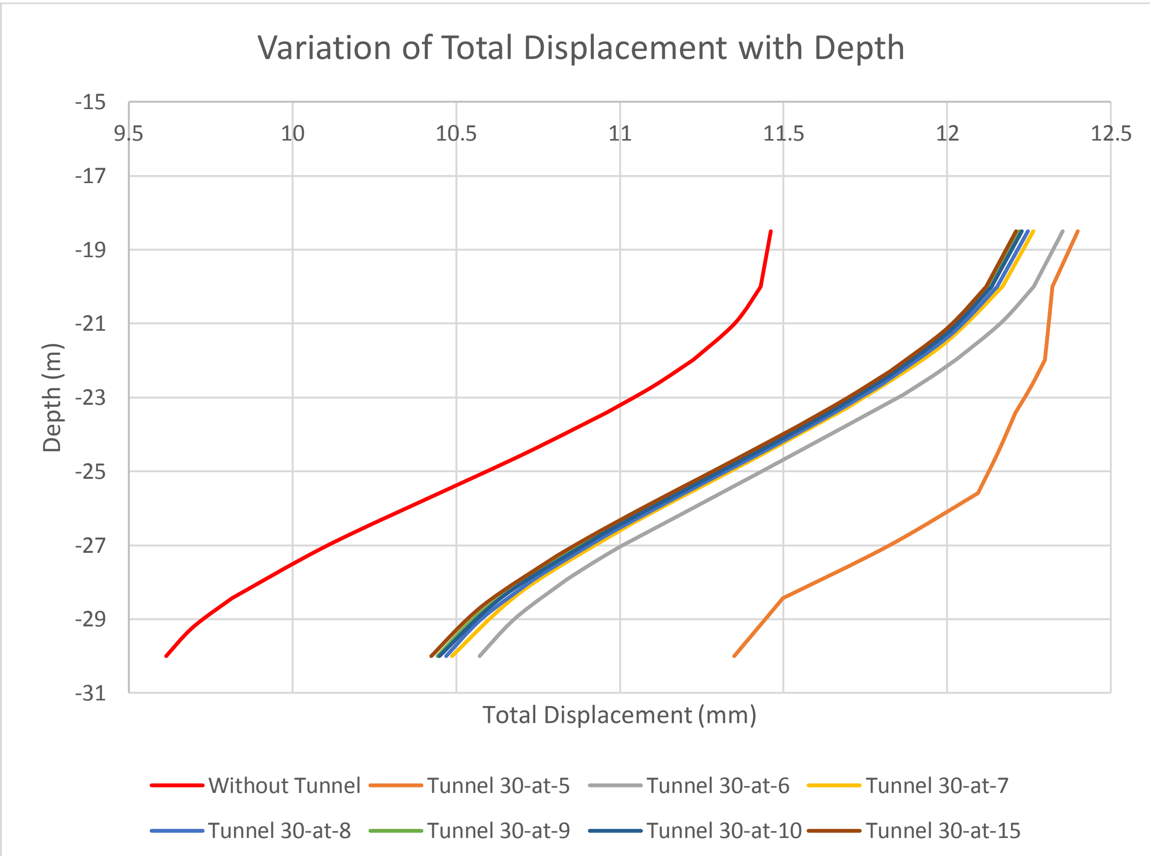


Figure 9 Displacement of pile over depth of pile, because of tunnel 'A' at various horizontal distances from the pile

As seen in the figure 9, the displacement is increasing as the distance between tunnel and pile decreases. When tunnel is away from the pile the displacement increase with the decrease in tunnel-pile distance is almost constant, but when tunnel is in the close vicinity (at distance of 5 m) of the structure, the displacement suddenly increases. Again displacement is more at a depth of centre of the tunnel.

4.4 Variation of total displacement of pile over depth of pile, because of tunnel 'A' at at various depths

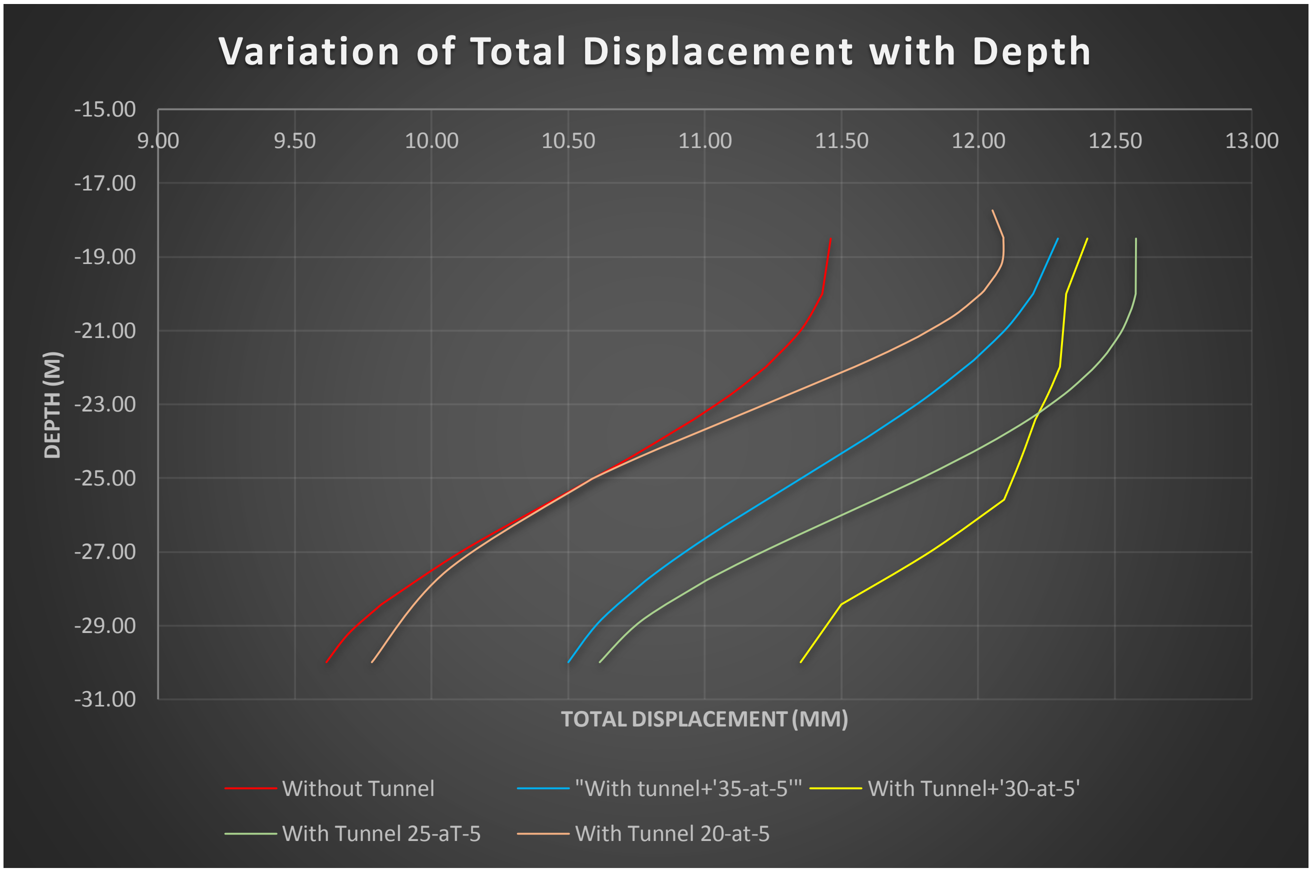


Figure 10 Displacement of pile over depth of pile, because of tunnel 'A' at at various depths

It is known that the displacement of pile increases with the presence of tunnel, but it also varies the location of tunnel. Here since tunnel '35-AT-5' is completely located in fractured basalt rock, it will not give more displacement, whereas the tunnel '30-AT-5' is located in stiff clay and is very close to the tip of pile and which gives maximum displacement.

Though the tunnel '20-AT-5' is located in clayey soil, still the position of tunnel is very far from the tip of the pile, so the displacement is lowest of all.

4. 5 Variation of total displacement with the horizontal distance between pile and tunnel

For better understanding here also we will take examples of tunnel fixed at -30m but going away horizontally from the pile. Let us compare between tunnels '30-AT-5', '30-AT-10' and '30-AT-15'

Figure 11 Displacement of pile, because of tunnel '30-AT-5'

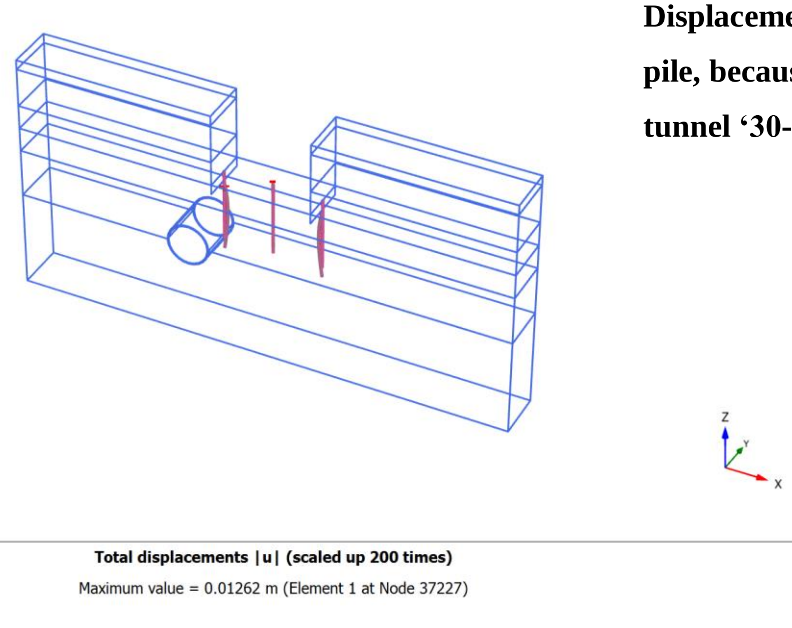
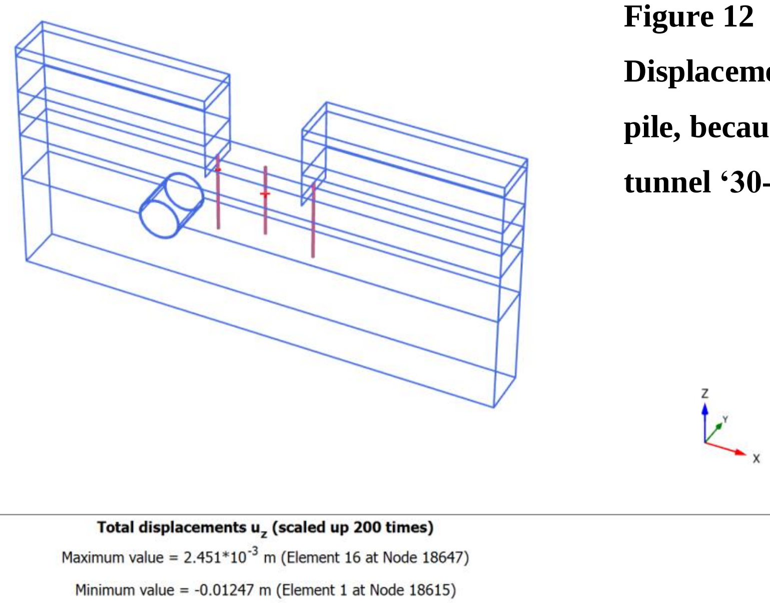


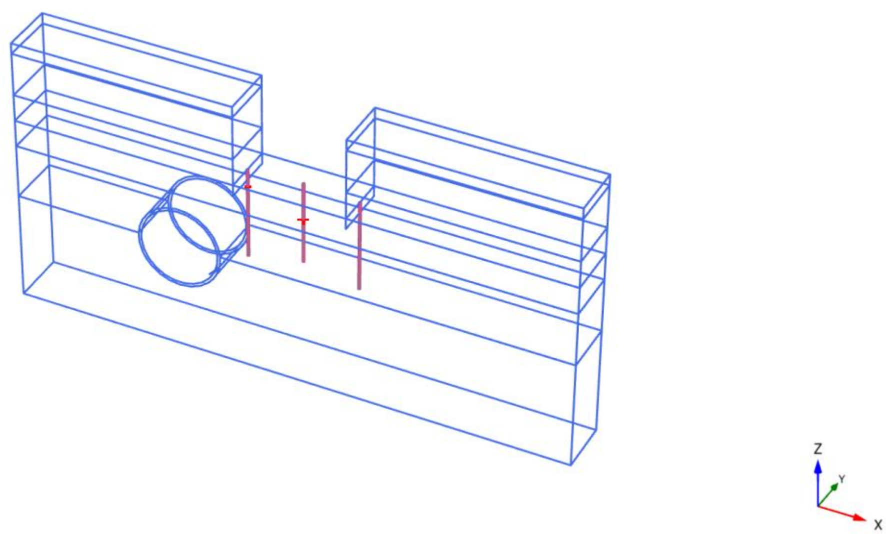
Figure 12 Displacement of pile, because of tunnel '30-AT-5'



As seen from figure 11 and 12, the displacement is more when tunnel is in close vicinity of the pile as compared to far away from the tunnel. The displacement further reduces as the distance between pile and tunnel increases.

4. 6 Variation of total displacement with the change in diameter of tunnel

The change in displacement of the pile because of presence of tunnel ’30-BT-10’ is shown in figure 13.



Total displacements u_z (scaled up 200 times)

Maximum value = 2.444×10^{-3} m (Element 16 at Node 18928)

Minimum value = -0.01254 m (Element 1 at Node 18895)

Figure 13 Displacement of pile, because of tunnel ‘30-BT-10’

The displacement of the tunnel at same depth and same distance from the pile, but with the less diameter (4.25 m) is 12.47mm. It clearly indicates that the displacement increases when diameter of the tunnel increases, though the variation in displacement is very less.

CHAPTER 5

CONCLUSION AND FUTURE SCOPE OF SYUDY

5. 1 Conclusion

In practical scenario, to manage heavy loads of multi storied building the provision of pile foundation becomes necessary. But in future, this pile foundation, being at large depths, may get affected by newly built tunnel passing close to it, so to predict effect of such tunnel on pile foundation becomes necessary. This project mainly deals with analysis of such pile foundation under the influence of tunnel with the use of finite element analysis software PLAXIS 3D.

After thorough analysis of results of simulation, following conclusions can be drawn out

1. Pile foundation of building is influenced by tunnel only when tunnel is in very close vicinity of pile and its influence is negligible if located far away from the structure.
2. The distribution of the tunnel induced internal forces strongly depends on the position of the pile tip with regard to the tunnel horizontal axis. The critical configuration corresponds to piles with a tip just below of the tunnel. When tunnel is located at various depths, the variation of total displacement with depth of pile depends upon position of tunnel and the tip of pile.
3. The diameter of tunnel also has small influence on displacement of pile. As the diameter increases the displacement of pile also increases.

5.2 Future scope of study

In following ways this work can be extended to get better results-

- The parameters other than displacement like skin friction, pile capacity can also be analysed. These result will be improved if tunnel loads are also considered.
- This analysis was carried out without considering vibration forces of the tunnelling process and also dynamic loading conditions when under traffic operational condition. Taking into account these forces, model can be made more realistic to get excellent results.
- If modelling of the advancement of Tunnel Boring Machine (TBM) is done with tunnel slowly approaching the neighbouring building, then various forces like grout pressure, face pressure of TBM also can be taken into account which may influence the result.

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